INTEGRATED SYSTEM FOR AND METHOD OF SUPPORTING SPATIAL DECISION MAKING AND LAND-USE SCENARIO ANALYSIS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/197,427, filed April 14, 2000.

BACKGROUND

Land-use planning has historically been a linear process in which land-use scenarios are created, considered, and then abandoned or implemented depending on the viability of the resulting scenario. This is a time-consuming, subjective, and reductive process that does not completely consider many important land-use factors because it is extremely difficult for a human analyst to generate, retain, and consider multiple scenarios in a short enough period of time to make a meaningful decision about a particular land-use issue.

Roughly fifteen to twenty years ago, Geographical Information System (GIS) software spatial tools made their entrance into the field of land-use planning, forever changing the way land-use planning is conducted. A GIS is an information system that is designed to work with data referenced by spatial or geographic coordinates. A GIS is both a database system with specific capabilities for spatially-referenced data, as well as a set of operations for working with the data. GIS color-coded maps and spatial analysis tools considerably simplified scenario analysis processes but, unfortunately, did not alter the fundamental nature of how scenario analysis was conducted; it still remained a linear and one-way process of reduction, which severely limits the variety of alternatives land-use planners have available to consider. This leads to inaccurate land-use forecasts, poorly imagined scenario alternatives, and potentially detrimental land-use plans. While a number of software tools have been introduced that attempt to address this issue, none work in an integrated fashion such that multiple land-use scenarios and factors can be modified and considered with near-simultaneity.

For example, U.S. Patent No. 5,818,737, "Method for guiding development of municipality," to Orr et al., describes a method for creating an electronic general plan for a municipality that is capable of providing projected results and effects based upon varying the inputted data as a function of the consequences of presently made or proposed decisions by

the decision makers of the municipality. A series of software modules utilize the data for a series of specific applications defined by the municipality. The output provided by modeling and simulation modules may be in the form of two- or three-dimensional visual presentations. Other patents that use GIS or related technology include U.S. Patents No. 5,835,386; 5,831,876; 5,818,737; 5,815,417; 5,808,916; 5,784,540; 5,671,381; 5,652,717; 5,555,354; 5,528,735; 5,193,185; and 4,969,114.

Land-use planning has traditionally been a linear and reductive process in which a restricted number of objectives can be considered due to the fact that only a small inventory of conditions, variables, parameters, and alternatives can be processed at a time. As the above-referenced patents demonstrate, the linearity problem persists. This has led to largely subjective side-by-side comparison of land-use scenarios and the adoption of less-than-optimal land-use solutions. Thus there is a need for a way to perform multi-objective land-use planning.

To devise optimal land-use plans, municipalities must consider a multitude of factors ranging from present and predicted growth patterns to resource availability thresholds to socioeconomic demographics, to name only a few. The consideration of such a wide array of factors requires extremely flexible software applications that can approach land-use analysis from analytical, visual, and predictive perspectives. While specialized applications exist for these types of tasks (see the above-referenced patents), they are often too limited in their scope to accommodate all types of analysis. This circumstance of limited tool flexibility leads land-use planners to make important decisions based on a restricted set of variables and assumptions. Thus there is a need for a way to integrate the analytical, visual and predictive evaluation of land-use scenarios.

Complete visualization of land-use scenarios is a key factor in understanding the real-world impact of those scenarios. Unfortunately, most existing land-use planning applications are unable to completely visualize land-use scenarios, much less integrate a visualization capability with other land-use planning tools. This has led to inefficient planning processes and ill-considered land-use plans. Thus there is a need for a way to perform land-use planning with integrated visualization.

In order for land-use planners to gain a complete understanding of how current decisions will impact future land-use directions, they must be able to forecast future

development patterns, such as population growth, traffic volumes, and housing density. While forecasting models exist, they are not presently integrated with applications that consider a wider range of land-use factors, and are therefore limited in their accuracy and usefulness. Thus there is a need for a way to better understand the future impacts of current decisions in land-use planning.

The consideration of a wide range of variables, conditions, relationships, and parameters is critical to the development of an optimal land-use strategy. Unfortunately, conventional land-use planning tools that are specialized in function allow the consideration and modification of a restricted number of variables and parameters. This results in the consideration of a limited number of land-use alternatives and, as a result, the selection of less-than-optimal land-use solutions. Thus there is a need for a way to provide the freedom to change any land-use planning variable or parameter.

Land-use planning processes have traditionally been laborious procedures in which a skilled technician may take days or even weeks to analyze potential impacts of alternatives. This has limited the amount of interaction that land-use planners have had in the land-use planning process, resulting in the less-than-ideal selection of land-use alternatives. The adoption of GIS tools has remedied this situation to some extent, but the process remains largely a one-way, reductive procedure in which real-time interaction is difficult, if not impossible. Thus there is a need for a way to interactively perform land-use planning in real-time.

Because land-use planners must often consider multiple scenario alternatives within a short period of time, the ability to perform land-use planning processes quickly and efficiently is critical to the success and adoption of an eventual solution. Unfortunately, conventional procedures for scenario analysis typically take days or weeks to conduct, severely restricting the number of scenarios that can reasonably be reviewed. Thus there is a need for a way to perform land-use planning rapidly.

SUMMARY

The present invention addresses the above needs, and further provides the following advantages over the above-cited references: (1) the invention provides multi-objective land-use planning capabilities; (2) the invention enables users to interactively perform

land-use planning in real-time; and (3) the invention integrates analytical, visual, and predictive evaluation of land-use scenarios.

Other advantages provided by the present invention include: (1) it provides a way to perform land-use planning with integrated visualization; (2) it provides the freedom to change any land-use planning variables or parameter; (3) it provides a way to perform land-use planning rapidly; and (4) it provides a way to better understand the future impacts of current decisions in land-use planning.

In a first aspect, the present invention comprises an integrated system for supporting spatial decision-making and land-use scenario analysis, preferably including: (1) a main unit that includes (a) a RAM device: (b) one or more CPUs; (c) a hard disk drive that stores (i) an operating system; (ii) a spatial database; (iii) third-party applications; and (iv) a preferred integrated software suite for spatial decision making (referred to herein as "Integrated Software Suite"); and (d) a high-speed graphics card; (2) a CD-ROM drive; (3) a high-resolution display; (4) a keyboard; and (5) a mouse.

In a second aspect, the present invention comprises software based on a topology for supporting spatial decision-making and land-use scenario analysis, including and integrating the following software: a 3D Visualization Module, further including a Model Library; a Desktop GIS, further including an Impact Analysis Module; and a Forecasting Module. This software is discussed in greater detail below.

In a third aspect, the present invention comprises an integrated method of supporting spatial decision-making and land-use scenario analysis, including the steps of: (a) installing Integrated Software Suite applications, including a Desktop GIS; (b) loading Integrated Software Suite extensions into the Desktop GIS; (c) creating a scenario view; (d) loading spatial data; (e) selecting an application; (f) determining whether appropriate impacts-modeling framework definitions exist; (g) determining whether appropriate terrain specifications exist; (h) determining whether a forecasting model is parametrized and calibrated appropriately; (i) defining an impacts- modeling framework; (j) experimenting with scenario alternatives and monitoring impacts; (k) specifying the terrain, draping an image and adding 3D features; (l) visualizing, modifying, and walking through scenario alternatives in 3D; (m) parametrizing and calibrating a forecasting model; (n) forecasting long-term implications of alternative scenarios and experimenting with policy options; (o) determining

whether to save a scenario for future reference; (p) saving the scenario; and (q) determining whether to continue exploring scenarios.

In a fourth aspect, the present invention comprises a method that provides real-time integration of spatial decision-making and land-use scenario software modules, comprising the steps of: (a) receiving a scenario data modification from a first module of an integrated software suite for spatial decision making; (b) recording the scenario data modification in a spatial database; and (c) alerting other modules of the software suite of the scenario data modification.

In a fifth aspect, the present invention comprises a method of providing a fully interactive and integrated planning tool in an integrated software suite for spatial decision making comprising spatial decision-making and land-use planning software modules wherein modifications made to land-use scenarios in one software module are immediately reflected in other modules, comprising the steps of: (a) enabling each module in the software suite to record each scenario data modification performed by that module in a common spatial database; (b) creating a clearinghouse hub that is capable of receiving notifications of scenario data modifications from each module and of immediately notifying all other modules of each scenario data modification; (c) enabling each module to immediately inform the clearinghouse hub of each scenario data modification performed by that module; and (d) enabling each module to respond to each notification of a scenario data modification received from the clearinghouse hub by immediately accessing the modified scenario data in the common spatial database.

In a sixth aspect, the present invention comprises an integrated software-based system for spatial decision making comprising: (a) a common spatial database; (b) a clearinghouse hub; and (c) a plurality of spatial decision-making and land-use planning software modules, wherein each module is operative to record in the common spatial database each scenario data modification performed by that module and operative to immediately inform the clearinghouse hub of each scenario data modification performed by that module; wherein the clearinghouse hub is operative to receive notifications of scenario data modifications from each of the modules and to immediately notify all other of the modules of each scenario data modification; and wherein each module is operative to respond to each notification of a

scenario data modification received from the clearinghouse hub by immediately accessing the modified scenario data in the common spatial database.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram of a personal computer ("PC") used in a preferred embodiment for supporting spatial decision-making and land-use scenario analysis

FIG. 2 depicts software topology for supporting spatial decision-making and land-use scenario analysis.

FIG. 3 illustrates steps of a preferred integrated method of supporting spatial decision-making and land-use scenario analysis.

FIG. 4 illustrates steps of a preferred method that provides real-time integration of spatial decision-making and land-use-scenario software modules.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention comprises an integrated system for and method of supporting spatial decision-making and land-use scenario analysis. The integrated method utilizes a software suite to conduct a real-time analytical, visual, and predictive evaluation of land-use scenarios. Modifications made to land-use scenarios in one software module are immediately reflected in other modules via a common spatial database, providing a fully interactive and integrated planning tool.

FIG. 1 illustrates a PC **100** used for supporting spatial decision-making and land-use scenario analysis. PC **100** includes a main unit **105**, a high-resolution display **140**, a mouse **160**, a keyboard **165**, and a CD-ROM drive **170**. Main unit **105** further includes one or more CPUs **110**, RAM **115**, a high-speed graphics card **120**, and a hard disk drive **130**. Hard disk drive **130** stores an operating system **132**, a spatial database **134**, third-party applications **136**, and Integrated Software Suite **138**.

Operating system **132** is preferably a commercially available operating system like Windows NT. Third-party applications **136** include commercially available GIS analysis and rendering programs, including, for example, such Desktop GIS products as ESRI's ArcView. Integrated Software Suite **138** preferably includes an Impact Analysis Module, a 3D

Visualization Module, and a Forecasting Module (although more, or fewer, modules could be included). These modules are described in greater detail below.

High-speed graphics card **120** is preferably an ultrahigh-speed graphics card using OpenGL, for 3D rendering. High-resolution display **170** supports third-party applications **136**, which are generally heavily graphic in nature, and is electrically connected to main unit **105**. Also electrically connected to main unit **105** are mouse **160**, keyboard **165**, and CD-ROM drive **170**.

In operation, third-party applications **136** and Integrated Software Suite **138** are installed on hard disk drive **130**. A user creates a scenario view using keyboard **165**, mouse **160**, and available data. The user then enters spatial data via keyboard **165**, CD-ROM drive **170**, or another data source, and spatial database **134** is updated accordingly. The user then defines a modeling framework using the separate modules of Integrated Software Suite **138**, creates various land-use planning scenarios, and views the visual results of these scenarios on high-resolution display **140**. Because of the integrated nature of Integrated Software Suite **138**, a change in any of the separate modules of Integrated Software Suite **138** is reflected in the other modules. As the user experiments with different scenarios, visualizes scenario alternatives, and forecasts long-term implications of scenario alternatives, spatial database **134** is continually updated to reflect the changes in the data.

FIG. 2 illustrates a software topology **200** used for supporting spatial decision-making and land-use scenario analysis. Topology **200** includes Integrated Software Suite **138** interfacing with Desktop GIS **240**. Desktop GIS **240** further includes spatial database **134**. Integrated Software Suite **138** further includes Impact Analysis Module **230**, 3D Visualization Module **250**, Forecasting Module **220** and Model Library **210**, as well as a clearinghouse hub module, discussed below.

Desktop GIS software and Impact Analysis, 3D Visualization, and Forecasting Modules are commercially available. For example, Environmental Systems Research Institute, Inc. (ESRI), in Redlands, California, markets *ArcView*, a Desktop GIS whose principle functions are viewing and querying spatial data. Other Desktop GIS products include Intergraph's *GeoMedia* and MapInfo Corporation's *MapInfo Pro*. *Scenario Constructor* is an Impact Analysis Module developed by the Orton Family Foundation, in Rutland, Vermont, that is a spatial impact analysis tool written in Avenue (ArcView's

exclusive object-based language). Other Impact Analysis products include Columbia University's *Smart Places*, Criterion Inc.'s *Smart Growth INDEX*, and Community Analysis and Planning Systems, Inc.'s *What If? PSS*. *TownBuilder 3D* is a real-time 3D Visualization Module written in C, C++, Visual Basic, and Avenue programming languages and developed by MultiGen-Paradigm, Inc., in San Jose, California. Other 3D Visualization products include Evans & Sutherland's *RAPIDSite Producer* and Terrex's *Terra Vista*. *Policy Simulator* is a Forecasting Module comprising an agent-based forecasting model written in the C, C++, Visual Basic, and Avenue programming languages and was designed and developed by PricewaterhouseCoopers, in New York, New York. Other forecasting products include *UGROW* developed by Prescott College. Those skilled in the art will recognize that these and other modules can be used in the present invention without departing from the spirit of the invention or the scope of the appended claims.

In operation, Integrated Software Suite **138** is installed on hard disk drive **130** as an extension of Desktop GIS **240**, which includes 3D Visualization Module **250**, Forecasting Module **220**, Impact Analysis Module **230**, and Model Library **210**. There is data communication via Desktop GIS's spatial database **134** between Impact Analysis Module **230**, 3D Visualization Module **250**, and Forecasting Module **220**, so that data modifications in one module may be reflected in the other modules. The method by which data modifications are reflected is described in the section below that refers to **FIG. 4**.

Process **300** is preferably executed using object-oriented computer programming, which allows a large number of step execution sequences. A preferred step execution sequence is shown in **FIG. 3**.

FIG. 3 illustrates an integrated method of supporting spatial decision-making and land-use scenario analysis, including the following steps:

Step **303** comprises installing Integrated Software Suite **138** and Desktop GIS **240**. In this step, a technical user installs Desktop GIS **240** and Integrated Software Suite **138** onto hard disk drive **130** via CD-ROM drive **170**. From the Integrated Software Suite **138**, the user must choose to install those applications that are most applicable to the eventual use of the Integrated Software Suite **138**. A complete installation of the Integrated Software Suite **138** includes Impact Analysis Module **230**, 3D Visualization Module **250**, Forecasting

Module **220**, and a Model Library **210**. Model Library **210** preferably contains 3D features, such as trees, houses, street signs, etc.

Step **305** comprises loading Integrated Software Suite extensions (modules) into Desktop GIS **240**. In this step, a technical user installs an Integrated Software Suite **138** extension into Desktop GIS **240**. Desktop GIS **240** software architecture accepts the installation of other software modules, known as extensions. The Integrated Software Suite **138** is installed as an Desktop GIS **240** extension such that when Desktop GIS **240** is executed and the Integrated Software Suite **138** extension is activated, the corresponding Integrated Software Suite **138** modules appear as menu functions within the Desktop GIS **240** functionality. Loading Integrated Software Suite **138** into Desktop GIS **240** causes two results: (1) an Integrated Software Suite **138** menu appears that extends the user functionality of Desktop GIS **240**, and (2) new document types become available, one of which is a scenario view (discussed below). The architecture for most commercially-available desktop GIS software products accepts installation of other software modules, commonly referred to as extensions.

Step **310** comprises creating a scenario view. In this step, a technical user who has knowledge of spatial modeling, Integrated Software Suite **138**, and Desktop GIS **240**, creates a Desktop GIS **240** map upon which spatial scenarios can be explored. For example, if a user wishes to explore scenarios associated with placing a shopping mall in Smalltown, USA, a scenario view entitled Smalltown Mall could be created. This forms the basis upon which all future scenarios involving a shopping mall in Smalltown, USA are performed. This is the empty framework upon which scenarios are explored.

Step **315** comprises loading spatial data. In this step, the technical user loads into Desktop GIS **240** GIS spatial data applicable to the geographic location and scenarios being explored. This data is preferably loaded from CD-ROM drive **170** and updates spatial database **134**. For example, the user might load road systems, current building locations, river locations, etc. This data defines the geographic location, as it exists at the present time (e.g., present day Smalltown, USA).

Step **320** comprises selecting an application. In this decision step, the technical user selects which of the Integrated Software Suite **138** modules should be set up first. This decision is based upon which application the user wishes to use and what function the user

wishes to accomplish. If the technical user selects Impact Analysis Module **230**, process **300** proceeds to step **325**; if the technical user selects 3D Visualization Module **250**, process **300** proceeds to step **335**; if the technical user selects Forecasting Module **220**, process **300** proceeds to step **345**.

Step **322** comprises ascertaining whether appropriate impacts-modeling framework definitions exist. In this decision step, a land-use planner determines whether appropriate impacts-modeling framework definitions exist. If yes, then process **300** proceeds to step **330**; if no, process **300** proceeds to **325**. For an initial scenario creation, the technical user creates appropriate impacts-modeling framework definitions.

Step **325** comprises defining an impacts-modeling framework. In this step, the technical user defines the impacts for a modeling framework within Impact Analysis Module **230**. This framework defines the modeling environment. During this process, the following relationships are typically defined: assumptions, constraints, causality relationships, and indicators. For example, if the user wishes to explore the traffic impacts of new development proposals, Impact Analysis Module **230** requires data, such as assumptions for traffic volumes from a new development, current traffic volume on existing roads, and apartment complex vs. single family unit traffic volume differentials. An example relationship could take the form: If an apartment building of X units is placed at a specific location, then a traffic volume of Y cars will appear on the highway.

Step **330** comprises experimenting with scenario alternatives and monitoring impacts. In this step, a land-use planner evaluates impacts of the scenario defined in steps **310** and **315**, generates derivative scenarios by varying the placement of features, changing attributes, and changing assumptions. The land-use planner also evaluates the impacts of the derivative scenarios.

Each modification of the scenario data in Impact Analysis Module **230** is immediately reflected in other Integrated Software Suite **138** modules (in a preferred embodiment, 3D Visualization Module **250** and Forecasting Module **220**). This is accomplished through the updating of spatial database **134** and the posting of events using integration protocols like dynamic data exchange (DDE) that alerts the other applications of a data change.

Each of the modules uses a common spatial-referencing system. While each of the modules produces results that are not necessarily spatial in nature (e.g., indicator results,

building appearance, or projected tax revenues), every result is produced within a spatial context. The scope of the spatial context used by all modules is established by the geographic extent and content of the data layers loaded into the scenario view (see **FIG. 3**, step **315**). This spatial environment is maintained, saved and retrieved as part of the scenario view (see **FIG. 3**, step **310**).

Because all modules use a common spatial-referencing system, the other modules in the suite, without further translation, can immediately and meaningfully interpret the spatial implications that result due to experimentation in any other module.

For example, suppose the layout for a proposed Master Plan is recorded in the common spatial database **134**. Forecasting Module **220** can be used to project new structures likely to be built over the next decade as a result of a proposed Master Plan. The spatial context for Forecasting Module **220**'s projection includes the locations (x-y coordinates) for each projected structure. These x-y coordinates are dynamically recorded in common spatial database **134**.

3D Visualization Module **250** also functions within the context of spatial database **134** and can readily interpret the x-y coordinates. However, 3D Visualization Module **250** might add visual context to this simple x-y location by associating it with placement on a mountainous terrain and/or by associating 3-dimensional models with unique appearances from the Model Library **210** for each coordinate. This allows the user to "see" the projected future from the Forecasting Module **220**. The visual "attributes" that are associated with the projected x-y coordinates are also dynamically recorded in common spatial database **134**.

Impact Analysis Module **230** also functions within the context of the same spatial database and can readily interpret not only the x-y coordinates, but the significance of the 3-dimensional attributes as well. Impact Analysis Module **230** might use this information to further compute impacts on local resources or drainage patterns. Unacceptable impacts may cause the user to modify the proposed Master Plan. This new layout is recorded in the common spatial database **134**. The process outlined above may repeat itself many times, providing the user with interactive, iterative, multi-objective analysis.

In a preferred embodiment, each module can "tag" any spatial data element with information specific to that module's integration requirements. The spatial database **134** used for establishing spatial context and results exchange between the modules of the suite is

typical of any common GIS spatial database. Distinct map "layers" exist which define various spatial characteristics of a location (e.g., road systems, water features, soil types, building locations, tax zones, etc.). To enable efficient interpretation and reaction to changes within the layers by the individual modules of the suite, an additional data layer tagging architecture is used. Any module can tag any spatial data layer. Multiple tags can exist for any data layer.

These "auxiliary data" tags include context-specific metadata required for operation of each module. Examples of spatial layer data tags used within the suite are a Forecasting Module policy lookup table associated with a particular tax zone data layer or a 3D Visualization Module's last known viewing position and direction within a 3-dimensional scene.

Software maintenance links are provided as part of the auxiliary data tag management system. Any module linked to the software suite can dynamically update the auxiliary data tags index using maintenance functions such as AddTag, SetTag, GetTag, and RemoveTag. The index of auxiliary data tags for each spatial data layer is maintained, saved, and retrieved as part of a scenario view (see **FIG. 3**, step **310**).

Each module responds dynamically to events posted by the other modules. In a preferred embodiment, each module has the capability to immediately reflect modifications made in other modules. The changes are recorded and exchanged via common spatial database **134**, as described above. The automatic response to these changes between modules is enabled by an event-posting architecture comprised in Integrated Software Suite **138**. This event-posting architecture is enabled by a common communication protocol such as DDE, OLE, or object-polling methodology. However, since the common exchange mechanism between modules of the suite is spatial, the events posted within this suite identify changes to the spatial context of the scenario. Also, events are multi-directional; any module can post an event to any other module. This multi-directional event posting is enabled by using an internal central clearinghouse module as a hub for posting of events. Each module posts its events to and "listens" for postings from the clearinghouse module. The clearinghouse module maintains the logic engine for appropriate responses to any posted event (updates impacts and/or posts subsequent events to other modules). Examples of events which might

be posted by any module concerning feature changes within the spatial database include: FeatureAdded, FeatureDeleted, FeatureModified (size or location), and FeatureHighlighted.

Steps of the preferred method of integrating spatial decision-making and land-use scenario modules described above are illustrated in **FIG. 4**. At step **410**, one of the modules ("Module A") receives a data modification ("change") to a scenario. This change typically occurs in steps **330**, **340**, or **350** (depending on which module happens to be "Module A") (see **FIG. 3**) as the user is experimenting with scenario alternatives within the context of Module A. The change could also occur during steps **325**, **335**, or **345**.

At step **420**, Module A records the change in common spatial database **134**. That is, the spatial implications of the change are recorded in common spatial database **134**.

At step **430**, Module A posts the change to the clearinghouse hub of Integrated Software Suite **138**. That is, the clearinghouse hub is informed by Module A that a change has occurred to the scenario.

At step **440**, the clearinghouse hub informs all other modules of the change. In this step. the clearinghouse hub immediately alerts all other modules that a scenario change has occurred.

At step **450**, other modules take appropriate action. Each module responds to the alert received from the clearinghouse hub appropriately. A module's response to a change typically includes interpreting results recorded in the common spatial database **134**.

Thus a preferred embodiment of the present invention comprises a method of providing a fully interactive and integrated planning tool in an integrated software suite for spatial decision making comprising spatial decision-making and land-use planning software modules wherein modifications made to land-use scenarios in one software module are immediately reflected in other modules, comprising the steps of: (a) enabling each module in the software suite to record each scenario data modification performed by that module in a common spatial database; (b) creating a clearinghouse hub that is capable of receiving notifications of scenario data modifications from each module and of immediately notifying all other modules of each scenario data modification; (c) enabling each module to immediately inform the clearinghouse hub of each scenario data modification performed by that module; and (d) enabling each module to respond to each notification of a scenario data

modification received from the clearinghouse hub by immediately accessing the modified scenario data in the common spatial database.

In an alternate (system) embodiment, the present invention comprises an integrated software-based system for spatial decision making comprising: (a) a common spatial database; (b) a clearinghouse hub; and (c) a plurality of spatial decision-making and land-use planning software modules, wherein each module is operative to record in the common spatial database each scenario data modification performed by that module and operative to immediately inform the clearinghouse hub of each scenario data modification performed by that module; wherein the clearinghouse hub is operative to receive notifications of scenario data modifications from each of the modules and to immediately notify all other of the modules of each scenario data modification; and wherein each module is operative to respond to each notification of a scenario data modification received from the clearinghouse hub by immediately accessing the modified scenario data in the common spatial database.

Returning to **FIG. 3**, step **332** comprises ascertaining whether appropriate terrain specifications exist. In this decision step, the land-use planner determines if appropriate terrain specifications exist. If yes, then process **300** proceeds to step **340**; if no, process **300** proceeds to **335**. For an initial scenario creation, the technical user creates appropriate terrain specifications.

Step **335** comprises specifying terrain, draping an image, and adding 3D features. In this step, a technical user utilizes 3D Visualization Module **250** to update spatial database **134** with (1) terrain descriptions within a spatial data layer, (2) a satellite or aerial photograph draped over the geography, and (3) additional features, such as trees and buildings. Features can be static (unchangeable) or dynamic (changeable). This step results in a 3D virtual location, e.g., a fully viewable Smalltown, USA. This virtual location can be navigated using mouse **160**.

Step **340** comprises visualizing, modifying, and walking through scenario alternatives in 3D. In this step, a land-use planner visualizes on high-resolution display **140** the virtual location set up in step **335**. The land-use planner may also alter, modify, or delete any dynamic feature. For example, the land-use planner may remove a tree or add a row of cars in front of a building. These changes are reflected in spatial database **134** and the other Integrated Software Suite **138** modules are alerted to the posted events, as described in step

330. The land-use planner may also navigate the virtual location from different perspectives ("flying" or "walking" through Smalltown, USA, for example) using mouse **160**. Navigation does not modify spatial database **134** but gives the land-use planner a sense of the visual impact of feature modifications. As with the other applications within Integrated Software Suite **138**, changes to the scenario are reflected in spatial database **134**, and the other Integrated Software Suite modules are alerted to the posted events through integration software, as discussed with respect to **FIG. 4**.

Step **342** comprises ascertaining whether the forecasting model in Forecasting Module **220** is parametrized and calibrated appropriately. In this decision step, the land-use planner determines whether the forecasting model is parametrized and calibrated appropriately. If yes, process **300** proceeds to step **350**; if no, process **300** proceeds to **345**. For an initial scenario creation, the technical user parametrizes and calibrates the forecasting model.

Step **345** comprises parametrizing and calibrating the forecasting model. In this step, a technical user parametrizes the Forecasting Module **220** forecasting model by entering current policies, population, zoning, census data, earning parameters within the virtual location of the scenario view created in step **310**. Ideally, parameters are entered for two time periods: (1) the present time and (2) sometime in history when this data was known. The technical user then calibrates the forecasting model by testing its predictions against changes that actually occurred over the given stated period. For example, the real-world changes within the time period 1990 - 2000 could be used to confirm the predictions of the forecasting model for that same time period. If the forecasting model does not accurately predict the real-world changes, the parameters are adjusted until the model predicts changes accurately.

Step **350** comprises forecasting long-term implications of alternative scenarios and experimenting with policy options. In this step, the land-use planner executes a simulation by running the Forecasting Module **220** forecasting model over a given time period with no policy changes. For example, the land-use planner may wish to know how Smalltown, USA will appear ten years from the present date given the current policies. The land-use planner may then make modifications to current policies, run the forecasting model again, and view characteristics (population, structure location, land values, etc.) of Smalltown, USA ten years in the future, given these changes. For example, the land-use planner may modify a zoning policy to reflect a much larger commercial zoning area in Smalltown, USA and then see how

this change affects the future characteristics of the town. As with the other applications within Integrated Software Suite, changes in policies and parameters are reflected in spatial database **134**, and the other Integrated Software Suite applications are alerted to the posted events through integration software, as discussed with respect to **FIG. 4**.

In step **355**, the land-use planner determines whether to save the current land-use scenario to hard disk drive **130** for future reference. If yes, process **300** proceeds to step **356**; if no, process **300** proceeds to **360**. In step **356**, the land-use planner saves the current scenario to hard disk drive **130**. In step **360**, the land-use planner decides whether to continue exploring land-use scenarios. If yes, process **300** returns to step **320**; if no, process **300** ends.

While the embodiments shown and described herein are fully capable of achieving the objects of the subject invention, it is evident that numerous alternatives, modifications, and variations will be apparent to those skilled in the art in light of the foregoing description. These alternatives, modifications, and variations are within the scope of the subject invention, and it is to be understood that the embodiments described herein are shown only for the purpose of illustration and not for the purpose of limitation.